CLAIMS

What is claimed is:

1. A method, a sensor array that employs a parameter to induce a time-varying phase angle φ on an optical signal that comprises a phase generated carrier based on a single frequency, the method comprising the step of:

calculating the time-varying phase angle φ through employment of a plurality of samples obtained approximately at a time t_s, wherein the plurality of samples are based on a plurality of mixed signals output from a mixer component that employs an input signal based on the optical signal of the sensor array.

2. The method of claim 1, wherein the step of calculating the time-varying phase angle φ through employment of the plurality of samples obtained approximately at the time t_s comprises the steps of:

mixing the input signal with one or more sinusoidal signals to create the plurality of mixed signals;

filtering the plurality of mixed signals to create a plurality of filtered signals;

sampling the plurality of filtered signals at the time t_s to obtain the plurality of samples; and

calculating the time-varying phase angle φ through employment of the plurality of samples.

3. The method of claim 2, wherein the step of mixing the input signal with the one or more sinusoidal signals to create the plurality of mixed signals comprises the steps of:

mixing the input signal with a sinusoidal signal $I_s(t) = \sin [4\pi f (t + t_0)]$ to create a mixed signal $M_{is}(t, \varphi)$;

mixing the input signal with a sinusoidal signal $I_c(t) = \cos [4\pi f (t + t_0)]$ to create a mixed signal $M_{ic}(t, \varphi)$;

mixing the input signal with a sinusoidal signal $Q_s(t) = \sin [2\pi f (t + t_0)]$ to create a mixed signal $M_{qs}(t, \varphi)$; and

mixing the input signal with a sinusoidal signal $Q_c(t) = \cos [2\pi f (t + t_0)]$ to create a mixed signal $M_{qc}(t, \varphi)$.

4. The method of claim 2, wherein the phase generated carrier comprises a modulation depth M, wherein the input signal comprises an interference term signal level B, wherein a function $J_1(M)$ comprises a first order Bessel function, wherein a function $J_2(M)$ comprises a second order Bessel function, wherein the step of filtering the plurality of mixed signals to create the plurality of filtered signals comprises the steps of:

filtering the mixed signal $M_{is}(t, \varphi)$ to create a filtered signal:

$$F_{is}(t,\varphi) = \int_0^t h(t-v)\cdot S(v,\varphi)\cdot I_s(v)\cdot env(v)\cdot dv\,;$$

filtering the mixed signal $M_{ic}(t, \varphi)$ to create a filtered signal:

$$F_{ic}(t,\varphi) = \int_0^t h(t-v)\cdot S(v,\varphi)\cdot I_c(v)\cdot env(v)\cdot dv\,;$$

filtering the mixed signal $M_{qs}(t, \varphi)$ to create a filtered signal:

$$F_{qs}(t,\varphi) = \int_0^t h(t-v)\cdot S(v,\varphi)\cdot Q_s(v)\cdot env(v)\cdot dv\,; \text{ and}$$

filtering the mixed signal $M_{qc}(t, \varphi)$ to create a filtered signal:

$$F_{qc}(t,\varphi) = \int_0^t h(t-v)\cdot S(v,\varphi)\cdot Q_c(v)\cdot env(v)\cdot dv\,.$$

5. The method of claim 4, further comprising the steps of:

calculating an in-phase term:

$$I_{mag}(t_s,\varphi) = \sqrt{F_{ic}(t_s,\varphi)^2 + F_{is}(t_s,\varphi)^2} \propto |\cos\varphi|\,;$$

calculating a quadrature term:

$$Q_{mag}(t_s,\varphi) = \sqrt{F_{qc}(t_s,\varphi)^2 + F_{qs}(t_s,\varphi)^2} \propto |\sin\varphi|\,; \text{ and}$$

calculating the time-varying phase angle φ through employment of the in-phase term $I_{mag}(t_s, \varphi)$ and the quadrature term $Q_{mag}(t_s, \varphi)$.

6. The method of claim 5, further comprising the steps of:

determining a sign of an in-phase term $I(t, \varphi)$, wherein the in-phase term $I(t, \varphi)$ comprises a magnitude equal to the in-phase term $I_{mag}(t, \varphi)$; and

determining a sign of a quadrature term $Q(t, \varphi)$, wherein the quadrature term $Q(t, \varphi)$ comprises a magnitude equal to the quadrature term $Q_{mag}(t, \varphi)$.

7. The method of claim 6, wherein the step of determining the sign of the in-phase term $I(t, \varphi)$ comprises the step of:

determining the sign of the in-phase term $I(t, \varphi)$ to be equal to a sign of the filtered signal $F_{ic}(t, \varphi)$ or $F_{is}(t, \varphi)$ with a largest magnitude;

wherein the step of determining the sign of the quadrature term $Q(t, \varphi)$ comprises the step of:

determining the sign of the quadrature term $Q(t, \varphi)$ to be equal to a sign of the filtered signal $F_{qc}(t, \varphi)$ or $F_{qs}(t, \varphi)$ with a largest magnitude.

8. An apparatus, a sensor array that employs a parameter to induce a time-varying phase angle φ on an optical signal that comprises a phase generated carrier based on a single frequency, the apparatus comprising:

a processor component that calculates the time-varying phase angle φ through employment of a plurality of samples obtained approximately at a time t_s, wherein the plurality of samples are based on a plurality of mixed signals output from a mixer component that employs an input signal based on the optical signal of the sensor array.

9. The apparatus of claim 8 in combination with the mixer component,

wherein the mixer component mixes the input signal with one or more sinusoidal signals from an oscillator component to create the plurality of mixed signals;

wherein the mixer component sends the plurality of mixed signals through a filter component to create a plurality of filtered signals;

wherein the processor component calculates the time-varying phase angle φ through employment of the plurality of samples based on the plurality of filtered signals.

10. The apparatus of claim 9, wherein the one or more sinusoidal signals comprise signals:

$I_s(t) = \sin[\,4\pi f\,(\,t + t_0\,)\,]$, $I_c(t) = \cos[\,4\pi f\,(\,t + t_0\,)\,]$; and

$Q_s(t) = \sin[\,2\pi f\,(\,t + t_0\,)\,]$, $Q_c(t) = \cos[\,2\pi f\,(\,t + t_0\,)\,]$;

wherein the mixer component mixes the sinusoidal signals $I_s(t)$, $I_c(t)$, $Q_s(t)$, and $Q_c(t)$ with the input signal to create the plurality of mixed signals:

$M_{is}(t, \varphi)$, $M_{ic}(t, \varphi)$, $M_{qs}(t, \varphi)$, and $M_{qc}(t, \varphi)$.

11. The apparatus of claim 10, wherein the phase generated carrier comprises a modulation depth M, wherein the input signal comprises an interference term signal level B, wherein a function $J_1(M)$ comprises a first order Bessel function, wherein a function $J_2(M)$ comprises a second order Bessel function;

wherein the mixer component sends the plurality of mixed signals $M_{is}(t, \varphi)$, $M_{ic}(t, \varphi)$, $M_{qs}(t, \varphi)$, and $M_{qc}(t, \varphi)$ through the filter component to create the plurality of filtered signals:

$$F_{qs}(t,\varphi) = \int_0^t h(t-v)\cdot S(v,\varphi)\cdot Q_s(v)\cdot env(v)\cdot dv\,,$$

$$F_{qc}(t,\varphi) = \int_0^t h(t-v)\cdot S(v,\varphi)\cdot Q_c(v)\cdot env(v)\cdot dv\,,$$

$$F_{is}(t,\varphi) = \int_0^t h(t-v)\cdot S(v,\varphi)\cdot I_s(v)\cdot env(v)\cdot dv\,, \text{ and}$$

$$F_{ic}(t,\varphi) = \int_0^t h(t-v)\cdot S(v,\varphi)\cdot I_c(v)\cdot env(v)\cdot dv\,.$$

12. The apparatus of claim 11 in combination with the filter component, wherein the filter component comprises a Gaussian low-pass filter, a fourth order Bessel filter, or a fourth order real pole filter.

13. The apparatus of claim 11, wherein the processor component employs the filtered signals F_{is} and F_{ic} to calculate an in-phase term:

$$I_{mag}(t_s, \varphi) = \sqrt{F_{ic}(t_s, \varphi)^2 + F_{is}(t_s, \varphi)^2} \propto |\cos\varphi|;$$

wherein the processor component calculates a quadrature term:

$$Q_{mag}(t_s, \varphi) = \sqrt{F_{qc}(t_s, \varphi)^2 + F_{qs}(t_s, \varphi)^2} \propto |\sin\varphi|;$$

wherein the processor component employs the in-phase term $I_{mag}(t, \varphi)$ and the quadrature term $Q_{mag}(t, \varphi)$ to calculate the time-varying phase angle φ.

14. The apparatus of claim 13, wherein the processor component employs the filtered signals $F_{ic}(t, \varphi)$ and $F_{is}(t, \varphi)$ to determine a sign of an in-phase term $I(t, \varphi)$, wherein the in-phase term $I(t, \varphi)$ comprises a magnitude equal to the in-phase term $I_{mag}(t, \varphi)$;

wherein the processor component employs the filtered signals $F_{qs}(t, \varphi)$ and $F_{qc}(t, \varphi)$ to determine a sign of a quadrature term $Q(t, \varphi)$, wherein the quadrature term $Q(t, \varphi)$ comprises a magnitude equal to the quadrature term $Q_{mag}(t, \varphi)$.

15. The apparatus of claim 14, wherein the processor component determines the sign of the in-phase term $I(t, \varphi)$ to be equal to a sign of the filtered signal $F_{ic}(t, \varphi)$ or $F_{is}(t, \varphi)$ with a largest magnitude;

wherein the processor component determines the sign of the quadrature term $Q(t, \varphi)$ to be equal to a sign of the filtered signal $F_{qc}(t, \varphi)$ or $F_{qs}(t, \varphi)$ with a largest magnitude.

16. The apparatus of claim 15, wherein the in-phase term I(t, φ) and the quadrature term Q(t, φ) comprise respective pulses centered near t_s;

wherein the processor component calculates the time-varying phase angle φ:

$$\varphi = \arctan\left(\frac{Q(t_s,\varphi)}{I(t_s,\varphi)}\right).$$

17. An article, a sensor array that employs a parameter to induce a time-varying phase angle φ on an optical signal that comprises a phase generated carrier based on a single frequency, the article comprising:

one or more computer-readable signal-bearing media; and

means in the one or more media for calculating the time-varying phase angle φ through employment of a plurality of samples obtained approximately at a time t_s, wherein the plurality of samples are based on a plurality of mixed signals output from a mixer component that employs an input signal based on the optical signal of the sensor array.

18. The article of claim 17, wherein the means in the one or more media for calculating the time-varying phase angle φ through employment of the plurality of samples obtained at the time t_s comprises:

means in the one or more media for mixing the input signal with one or more sinusoidal signals to create the plurality of mixed signals;

means in the one or more media for filtering the plurality of mixed signals to create a plurality of filtered signals;

means in the one or more media for sampling the plurality of filtered signals to obtain the plurality of samples; and

means in the one or more media for calculating the time-varying phase angle φ through employment of the plurality of samples.

19. The article of claim 18, wherein the means in the one or more media for mixing the input signal with the one or more sinusoidal signals to create the plurality of mixed signals comprises:

means in the one or more media for mixing the input signal with a sinusoidal signal $I_s(t) = \sin[4\pi f(t + t_0)]$ to create a mixed signal $M_{is}(t, \varphi)$;

means in the one or more media for mixing the input signal with a sinusoidal signal $I_c(t) = \cos[4\pi f(t + t_0)]$ to create a mixed signal $M_{ic}(t, \varphi)$;

means in the one or more media for mixing the input signal with a sinusoidal signal $Q_s(t) = \sin[2\pi f(t + t_0)]$ to create a mixed signal $M_{qs}(t, \varphi)$; and

means in the one or more media for mixing the input signal with a sinusoidal signal $Q_c(t) = \cos[2\pi f(t + t_0)]$ to create a mixed signal $M_{qc}(t, \varphi)$.

20. The article of claim 18, wherein the phase generated carrier comprises a modulation depth M, wherein the input signal comprises an interference term signal level B, wherein a function $J_1(M)$ comprises a first order Bessel function, wherein a function $J_2(M)$ comprises a second order Bessel function, wherein the means in the one or more media for filtering the plurality of mixed signals to create the plurality of filtered signals comprises:

means in the one or more media for filtering the mixed signal $M_{is}(t, \varphi)$ to create a filtered signal $F_{is}(t,\varphi) = \int_0^t h(t-v) \cdot S(v,\varphi) \cdot I_s(v) \cdot env(v) \cdot dv$;

means in the one or more media for filtering the mixed signal $M_{ic}(t, \varphi)$ to create a filtered signal $F_{ic}(t,\varphi) = \int_0^t h(t-v) \cdot S(v,\varphi) \cdot I_c(v) \cdot env(v) \cdot dv$;

means in the one or more media for filtering the mixed signal $M_{qs}(t, \varphi)$ to create a filtered signal $F_{qs}(t,\varphi) = \int_0^t h(t-v) \cdot S(v,\varphi) \cdot Q_s(v) \cdot env(v) \cdot dv$; and

means in the one or more media for filtering the mixed signal $M_{qc}(t, \varphi)$ to create a filtered signal $F_{qc}(t,\varphi) = \int_0^t h(t-v) \cdot S(v,\varphi) \cdot Q_c(v) \cdot env(v) \cdot dv$.

21. The article of claim 20, further comprising:

means in the one or more media for calculating an in-phase term:

$$I_{mag}(t_s,\varphi) = \sqrt{F_{ic}(t_s,\varphi)^2 + F_{is}(t_s,\varphi)^2} \propto |\cos\varphi|;$$

means in the one or more media for calculating a quadrature term:

$$Q_{mag}(t_s,\varphi) = \sqrt{F_{qc}(t_s,\varphi)^2 + F_{qs}(t_s,\varphi)^2} \propto |\sin\varphi|; \text{ and}$$

means in the one or more media for calculating the time-varying phase angle φ through employment of the in-phase term $I_{mag}(t, \varphi)$ and the quadrature term $Q_{mag}(t, \varphi)$.

22. The article of claim 21, further comprising:

means in the one or more media for determining a sign of an in-phase term $I(t, \varphi)$ to be equal to a sign of the filtered signal $F_{ic}(t, \varphi)$ or $F_{is}(t, \varphi)$ with a largest magnitude; and

means in the one or more media for determining a sign of a quadrature term $Q(t, \varphi)$ to be equal to a sign of the filtered signal $F_{qc}(t, \varphi)$ or $F_{qs}(t, \varphi)$ with a largest magnitude.

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